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PLANNING and DESIGNING SCHOOL COMPUTER FACILITIES

Finance and Administration

Alberta
EDUCATION

PLANNING AND DESIGNING
SCHOOL COMPUTER FACILITIES
INTERIM REPORT
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PREFACE

School computer facilities are a new phenomenon, and as such represent an exciting challenge to facility planners and designers. This publication, Planning and Designing School Computer Facilities, is intended to help meet this challenge, through providing suggestions and considerations that will be useful in developing facilities for computers in schools. The report emphasizes facility planning considerations as well as design requirements and criteria, so that it will assist in the design and implementation of the specific school computer facilities required to fulfill local educational needs.

Planning and designing school computer facilities is a new and rapidly developing expertise. Experience and knowledge is being gained almost daily by those providing school computer facilities throughout the province. This study is being brought forward as an interim report and circulated for use and review by interested individuals to draw upon this first-hand experience. Suggestions and contributions you may wish to make are welcomed for inclusion in a second edition to be published in one year. It is our intent that the second edition contains more specific and detailed information and be revised through feedback from users.

ACKNOWLEDGMENTS

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Appreciation is expressed to the many school systems who responded to requests for suggestions and concerns related to the planning and designing of school computer facilities. In particular the contributions are acknowledged of Gordon Branson (Calgary Public Schools), J.J. Gleason (Lethbridge Catholic Separate School District No. 9) and W. Evdokinoff and Wayne E. Krywolt (Lethbridge Community College) who provided tours of their facilities and insight into their planning and design experiences.

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SECTION I

INTRODUCTION

A. PURPOSE AND SCOPE

The purpose of this publication is to provide suggestions and considerations which may be useful for school jurisdictions developing facilities for computers in schools. It is intended to assist school system planners in clarifying the educational specifications necessary for them to give adequate direction to architects, other design consultants and purchasers involved in the design and implementation of school computer facilities.

In Part II of this document emphasis is placed on planning considerations while Part III focuses on design requirements and criteria. Part II discusses the following: planning process, needs assessment, computer locations, security, health and safety concerns, hardware and software considerations, maintenance and operation, and budget aspects. In Part III attention is given to: design of workstations, laboratory configurations, and to architectural, electrical and mechanical design criteria. Sketches are provided to assist in clarifying the concepts discussed.

Detailed consideration of software and hardware selection criteria and provisions for maintenance are beyond the scope of this document. Hardware and software references have been restricted to impacts on building planning and design.

B. LIMITATIONS

While a survey of the literature in the last five years in North America, Britain and Australia has been carried out during the preparation of this publication, the results have been meagre in the finding of research which provides hard data relating directly to school computer facility design. The user of this document should be aware that the suggestions provided are largely based on studies in office automation and so they are largely untested and unevaluated in the school and classroom setting.

SECTION II

PLANNING SCHOOL COMPUTER FACILITIES

A. THE PLANNING PROCESS

1. Planning Phases

If planning for school computer facilities is not to be haphazard, it should be carried out in accordance with a planning model. This model should address questions of the school's needs, the purpose of the computer facility, specific plans to achieve an operational facility and maintenance requirements. Lundgren and Garrett (1985) provide a checklist or outline encompassing four phases: study phase, design phase, development phase and an operation phase. This outline is reproduced in Table 1. A model such as this one will assist in ensuring that important considerations have not been overlooked.

2. The Planning Team

School computer facility planning requires a variety of expertise. For this reason, consideration should be given to establishing a planning team along the following lines:

Study Phase:	representatives of central and school administration (one to be designated as "team coordinator"), teachers, local and provincial curriculum consultants;
Design Phase:	architect, electrical and mechanical consultants, facilities manager, equipment suppliers and Study Phase team members;
Development Phase:	purchasing agents, suppliers and Study Phase team members;
Operation Phase:	representatives of school administration and users.

TABLE I
MICROCOMPUTER LABORATORY OUTLINE

I. STUDY PHASE: Analysis of Needs

A. Major Considerations
  1. Statement of Purpose
     Administrative, curricular, community, and extracurricular
  2. Utilization Profile
     Number of individuals and peak usage
  3. Current and Future Funding Commitment
     Hardware and software purchases; staffing

B. Study Phase Report
  1. Statement of Purpose and Direction
  2. Summary of Accomplishments to Date
  3. General Recommendations

II. DESIGN PHASE: System Design

A. Design Ideal Configuration
  1. Computer Hardware
     Number of stations, minimal capabilities, software and service availability, peripherals, security, and compatability considerations
  2. Software
     Functional type specifications, proprietary considerations, and security
  3. Network Configuration
     Full networking including peripherals, partial networking, stand-alone
  4. Physical Laboratory Facilities
     Space, size and storage considerations, ergonomics, safety, ambient temperature control, and the electronic environment
  5. Supervision
     Students, paraprofessional, or professional supervisors
  6. Policies and Procedures
     Scheduling access policies and procedures, and management/security (disk/paper)

B. Cost Estimating
   Hardware, Software, Environment, and Personnel

C. Cost/Benefit Analysis

D. Design Revision (as necessary)

E. Final Design Phase Report

III. DEVELOPMENT PHASE: System Implementation

A. Purchasing

B. Installation and Testing

C. Training/Orientation (Lab Directors/Supervisors)

D. Final Development Project Report

IV. OPERATION PHASE: Evaluation and Maintenance

A. Hardware/Software Replacement Plan

B. Policies for Upgrading Software/Hardware

C. Evaluation Instruments and Intervals

D. Procedures for Equipment in Service

E. Annual/Quarterly Report

(Lundgren and Garrett, 1985)

B. NEEDS ASSESSMENT

In carrying out a needs assessment attention should be given to the functions or purposes intended for the facility. Further, the potential users must be identified as well as the activities in which they will be engaged while using the facility.

1. Functions Served

A study of the purposes or functions which will be served by the school computer facility should carefully examine the instructional uses which will be served, and whether other than instructional uses will be made. In particular, will the facility also be employed for administrative and/or recreational uses? A definition of potential uses will have an important bearing on security, access and location planning for the facility as well as on hardware and software needs. Will the facility be used outside of ordinary school times? What courses will be offered in the facility?

2. Users to be Served

A description should be made of potential facility users. Included in the description should be: age range, total and peak usage numbers, type of user (students, non-students, users with physical handicaps, casual users), mode of use (singly, groups, classes). The result should be a utilization profile which will assist in determining facility size, location, furniture sizes and configuration, policies on scheduling, supervision and security. An analysis of the utilization profile should lead to a consideration of priorities which may need to be established.

3. User Activities

Depending on the functions to be served and the types of users, the activities which will occur in the facility may vary. Will the facility be used for both teaching and practice or for either alone? Will it be used for data entry and for retrieval for administrative purposes? Table 2 contains a listing of possible student and teacher activities to be considered. An analysis of user activities will assist with designing workstation and computer laboratory configurations.

TABLE 2

USER ACTIVITIES

Student Activities	Teacher Activities
Data entry	Data entry
Text entry/edit	Text entry/edit
Information retrieval	Information retrieval
Reading non-VDT material	Reading non-VDT material
- printouts	- printouts
- textbooks	- textbooks
- projected material	- projected material
Listening	Listening
- to teacher	- to student(s)
- to other student(s)	- to recorded material
- to recorded material	
Speaking	Speaking
- to teacher	- to student(s)
- to other students	
Writing	Writing
- note taking	
- editing printouts	
- flow-charting	- on overhead projector
- tests and exams	
Monitoring teacher activities	Monitoring student activities
- direct VDT observation	- direct VDT observation
- electronic VDT viewing	- electronic VDT viewing

C. LOCATION OF FACILITIES

Factors to be considered in locating computer facilities include balancing access requirements arising out of the needs assessment with security requirements. The latter concern will be discussed in the next section. A further factor which must be studied is the relative effectiveness of locating computers in particular school locations.

The Center for Social Organization of Schools of the Johns Hopkins University conducted the National Survey of School Uses of Microcomputers in 1983. This study encompassed 1,082 schools in the U.S.A. The effects of the location of microcomputers in schools is reported by Becker (1984). The review concluded the following:

- When computers are located only in classrooms, there is less, but more equitable use;
- The impact of having a computer laboratory is that there is more use with emphasis on programming;
- Where computers are located in the school library in secondary schools, there is less use than if they were located in a lab, but more use than if located in classrooms. Further, there are fewer different uses made of the computers and more of a balance between programming and drill and practice uses. In elementary schools with computers located in the library there was more balance in use between above-average and below-average students but less positive social outcomes. In the latter instance, student enthusiasm for computers was particularly low in elementary schools when computers were located in the media centre;
- Rotating microcomputers from room to room results in more access but less impact on students and schooling;
- Dispersing microcomputers around the school does not appear to be beneficial for elementary schools, but has certain benefits for secondary schools;
- In most cases, further research is required to discover the reasons for the effects noted in this study.

It is apparent that there is no single best solution to the question of location. The results of the research must be weighed in relation to the school's objectives for its computer programs. A summary of the Becker study is given in Table 3.

TABLE 3

SUMMARY: IMPACT OF MICRO LOCATIONS ON PATTERNS OF USE

Note: Each row-column combination has two entries. The Format is...

ELEMENTARY ENTRY / SECONDARY ENTRY. The entries are:

+ : Substantially More in These Schools Than in Other Schools

- : Substantially Less in These Schools Than in Other Schools

	Classrooms Only	Computer Lab	Library	Rotate Micro Between Rooms	Dispersed Locations
Number of Regular Teacher Users	- / -	+ / +	/ +	/ +	/ +
Number of Hours Per Week of Student Use	/ -	+ / +	/	/ +	- /
Breadth of Use Across 13 Applications	- /	/ +	/ -	/	/ +
Percent of Students Who Use Micro	/	+ /	/ +	+ / +	/ +
Dominance of Computer Programming Uses Over Drill-and-Practice	- / -	+ / +	/ -	- /	+ / -
Equity Between Above-Average and Below-Average Students' Use	/ +	- / -	+ /	+ /	/
Computer Time Per Student User	- / -	/ +	/	- /	- /
Academic Learning Attributed To Micro Presence	/	/	- /	- /	/
Social and Organizational Outcomes Attributed to Microcomputer	/	/	- /	- / -	- /

(Becker, 1984)

D. SECURITY AND LEGAL CONSIDERATIONS

The need for computer security only arises if there is something valuable associated with computers which needs to be protected. Protection should be considered for the following reasons: eliminating unauthorized use (hardware, software, data, phone links), securing (maintaining) accuracy of data for instructional and/or administrative use, maintaining confidentiality of certain data (student records), replacing stolen or vandalized software/hardware, eliminating loss of instruction time when loss occurs (particularly to senior high students in semestered computer courses) and reducing loss or waste of staff time while computers are out of service. The local cost of some types of loss can be minimized by adequate insurance but even in these cases the insurance cost is eventually borne by the community generally. Special provisions must be made, however, to provide viable alternatives for teachers and students in the event of extended unavailability of school computers.

1. Threat Assessment

Because security provisions are a cost item, it is important that resources allocated to security be directed to those areas where there is a high cost/benefit. To determine such areas, a threat assessment should be carried out which identifies the nature of the threat, assigns a probability of an actual breach of security and estimates the resulting level of loss. The resulting index of exposure will identify the highest cost/benefit security factors. A suggested format for carrying out a threat assessment is contained in Table 4. More extensive approaches are contained in the security system review manual published by the American Federation of Information Processing (AFIPS) cited in the references at the end of this publication.

2. Review of Existing Security

With the threat assessment in hand, a review of existing security arrangements and plans should be made to identify strengths and weaknesses.

3. The Security Plan

A written security plan should be developed. This plan should be directed at protecting data, software and hardware from theft and harm by restricting physical access to authorized persons, providing locks on doors and windows, providing intrusion alarms, securing terminals to furniture, preventing physical access to internal parts of computers, and keeping back-up copies of programs and data and storing them separately.

A contingency plan for loss or failure of computers should be developed by prearranging replacement or access to alternative computer sites in cooperation with other schools and equipment suppliers.

The security plan should also give consideration to controls on electronic access by means of passwords, screening of dial-ups prior to log-on, and by shutting off for specified times electronic access to the computer. Controls should also be placed on access to outside on-line data bases and financial controls on telecommunications (long distance) charges.

4. Legal Aspects of Security

A review of current cases and proposed legislation (Kingston, 1985) indicates that the courts will not protect computer owners who have not made reasonable security provisions. Bill C-18 will amend the Criminal Code of Canada to make it a crime to wilfully destroy, alter or interfere with the use of data. It will also make it an offence to knowingly without authorization obtain a computer service, intercept a function of a computer system, and to use a computer to do either of the above. Recent court cases have established that confidential information is property, that a list (data or program) compiled on a computer is subject to copyright. In the U.S. companies have been held liable for unauthorized copying of programs by employees.

Policy should be developed to ensure compliance with licence and copyright agreements for print material and software which accompany the purchase of such materials. Failure to comply with such, often implicit, agreements could result in breach of contract with the vendor.

TABLE 4

SUGGESTED THREAT ASSESSMENT FORMAT

Threat	Probability (P) Of Occurrence High 3 Moderate 2 Low 2 None 0	Level of Loss (L) High 3 Moderate 2 Low 1 None 0	Exposure(E) (P x L)
	P	L	E
NATURAL			
Wind			
Earthquake			
Fire			
Flood			
Other			
MAN-MADE			
Fire/Water			
Riot			
Strike			
Accident			
Loss of Utilities			
HOSTILE ACTION			
Theft			
Fraud			
Mischief			
Sabotage			
SYSTEM UNRELIABILITY			
Hardware			
Software			
Applications			
Communications			
Human Errors			

Note: In calculating level of loss consideration should be given to cost of replacement of hardware, software, time to rebuild lost data and text, and lost staff time and instruction time of students. For items indicating high exposure, level of loss should be estimated in dollars per year. This amount would indicate the upper limit of investment in prevention which would provide a benefit.

5. Policy Requirements

It is suggested (Jeffrey, 1985) that a security plan be part of an official information policy which addresses information management, the privacy of information, use of computer resources and access to information. The policy should define what is sensitive and to be protected as well as the penalty for infringement. It should further provide for regular communication of the policy to all computer users.

E. HEALTH AND SAFETY CONSIDERATIONS

There has been a good deal of public discussion concerning health effects of video-display terminal use. This prompted the U.S. National Institute for Organizational Safety and Health (NIOSH) to survey the health complaints associated with VDT use. The results indicated a significantly larger number of health complaints among VDT users as compared with control subjects. The results of the survey are contained in Table 5. The report included recommendations for adult computer stations which are contained in Table 6. The significance of these findings for school facility planning is stressed by Yeaman (1983) who foresees considerable resistance to computer use by students developing in the long term if facilities planning disregards student health concerns. This will require the application of human factors research (ergonomics) to the planning of school computer facilities.

Unfortunately, little research has been done regarding the physical arrangements required by children using micro-computers. While it can be argued that students will not be spending as much time with computers as do business operators, Yeaman notes that student physical and psychological immaturity is likely to intensify the stress induced by the body rigidity brought about with use of a computer screen and keyboard.

The best that can be done until more research results on child ergonomics become available is to adapt the NIOSH recommendations to the school situation. Yeaman further suggests that students should be taught to adjust workstations; that complaints of discomfort by students be taken seriously; that time limits and rest breaks be incorporated into class routines; and that students be advised to have vision testing as computer use reveals undetected vision problems and vision complications for students wearing glasses or contact lenses.

Underlying the facility planning approach should be the ergonomic principle of requiring the facility to be adaptable to the person rather than requiring the person to adapt to the facility.

TABLE 5

PERCENTAGE OF CLERICAL VDT OPERATORS AND CONTROL SUBJECTS WITH SELECTED HEALTH COMPLAINTS

Health Complaints	Percentage	
	Clerical VDT	Control Subject
Skin Rash	57	31
Irritability	80	63
Fainting	36	17
Nervousness	50	31
Fatigue	74	56
Pain Down Arm	36	20
Stomach Pains	51	35
Change in Color Perception	40	9
Irritated Eyes	74	47
Burning Eyes	80	44
Blurred Vision	71	35
Eye Strain	91	60
Swollen Muscles and Joints	50	25
Back Pain	78	56
Painful or Stiff Arms or Legs	62	35
Painful or Stiff Neck or Shoulders	81	55
Numbness	47	18
Neck Pressure	57	34
Difficulty with Feet from Standing Long Periods	49	35
Sore Shoulder	70	38
Loss of Feeling in Wrists or Fingers	33	11
Neck Pain into Shoulder	56	19
Hand Cramps	49	16
Loss of Strength in Arms or Hands	36	14
Stiff or Sore Wrists	47	7

(NIOSH, 1981)

TABLE 6

NIOSH RECOMMENDATIONS FOR ADULT COMPUTER STATIONS (VIDEO DISPLAY TERMINALS)

Workstation Design Features

Chair. The chair should have a seat pan which is adjustable in height. The mid-back or lumbar region should be provided with support by a back rest. The feature of height adjustment is desirable, as is a setting for tension. Stability is provided by a base resting on five castors.

Leg Clearance. Leg clearance between knees and counter is essential.

Footrest. Footrests are very necessary for short users.

Keyboards. The height of all keyboards should be adjustable. Each keyboard should be between 0.74 and 0.79 meters above the floor, as measured from the home row on the keyboard.

Optical Concerns

Viewing Distance. The eye to screen distance should be variable between 0.45(18 in.) and 0.5(20 in.) meters. The viewing distance should be comfortable and adjustable to each viewer's needs. The keyboard and copyholder for frequently referred to documents should be in the same plane as the screen and of the same viewing distance. This prevents visual fatigue from continuous refocusing. The copyholder is indispensable in word processing and similar activities.

Viewing Angle. The screen's top edge should be no higher than eye level - 0 degrees - and no more than 40 degrees below. The ideal range is for the center of the screen to be at 10 degrees - 20 degrees below the horizontal plane at the user's eye height. The screen should be at a right angle to the line of sight - just like a book.

Lighting Level. For reading computer screens, the lighting level should be a third to a half of that normally used for reading printed paper. A level between 500 and 700 lux (45 to 65 foot-candles) would be correct for reading both. The print to background contrast minimum is 5:1. Brightness and contrast of the screen should be accessible for adjustment to each user's needs.

Lighting Contrast. The luminance ratio within the user's field of vision should be 1:3 in the center - the desk area - and not exceed 1:10 in the periphery - the room. Surfaces which reflect highly should be eliminated. Cutting down reflectivity through the excessive use of dark colours is not in order because dark colours may generate negative emotions.

Reflective Glare. Reflective glare (See Figure 2) is undesirable since it causes eye fatigue. To eliminate reflective glare, there are three mandates:

(1) Windows should be shaded;
(2) Screens should be positioned so as not to reflect windows or overhead lights; and
(3) The viewing direction of the user should run parallel to such light sources and avoid direct glare.

If reflective glare is still present, there are remedial steps:

(1) Full or partial screen hoods may be fitted;
(2) Anti-glare filters may be attached to the screens;
(3) Fluorescent light fixtures may need to be recessed; baffles may have to be added to cause more even diffusion of light by directing the light downward;
and
(4) An indirect lighting system may have to be installed.

(NIOSH, 1981)

F. HARDWARE CONSIDERATIONS

The specifications of computer hardware, communications and networks selected for use in a school computer facility have important ramifications for furniture design, architectural design, and for electrical and mechanical requirements. For these reasons it is recommended that a representative of the hardware supplier be part of the facility planning team. This implies that the hardware supplier should be selected or determined prior to commencement of detailed facility designing and specification development.

G. OPERATION AND MAINTENANCE CONSIDERATIONS

Attention to operation and maintenance concerns needs to be addressed in school computer facility planning.

1. Custodial Requirements

Furniture and room layout planning should take into consideration the elimination of features which reduce the efficiency and effectiveness of computer facility custodial service. Because poor air cleanliness directly affects the operation of disc drives in particular, dust control becomes an important planning factor.

2. Hardware Maintenance

Provision should be made for space and equipment needed by school staff to carry out necessary preventive maintenance and equipment adjustments. Such space may also be required for major maintenance to be carried out on-site by out-of-school staff or by servicing agencies. It is suggested that a comprehensive maintenance plan be developed as part of the planning process for a school computer facility.

3. Software Maintenance

Because software may require maintenance to correct errors of design, logic and coding, or to make changes to adapt to changing requirements or to implement enhancements, space and access (electronic and physical) need to be provided for programmers to work. Again, attention should be given to developing a software maintenance plan as part of the planning process.

H. BUDGET CONSIDERATIONS

Successful implementation of a plan to operate a computer facility requires an adequate budget which considers a comprehensive range of cost factors both in the immediate and in the long range. While outlays for computer hardware are significant in comparison to other forms of educational technology many other related costs must be considered. Among these Hales (1984) notes the following:

1. Hardware, including cabling and accessories and shipping.
2. Software, including applications and licence fees.
3. Installation of hardware and software including utility hookups, air conditioning, fire protection, furniture and vendor fees.
4. Training fees and expenses for staff.
5. Maintenance of hardware and software.
6. Supplies, paper, forms, printer ribbons, etc.
7. Utilities including, power, water, sewer, telephone and data lines.
8. Insurance on computer system, software and data.
9. Personnel.
10. System selection and evaluation costs.
11. Data entry to load up the system data base initially.

The emergence of the micro-computer on the school scene is too recent to provide hard data on relative costs of the factors noted above. Torok (1984) does provide the following rule of thumb:

HARDWARE \$\$\$ = SOFTWARE \$\$\$ and,
HARDWARE \$\$\$ + SOFTWARE \$\$\$ = MAINTENANCE \$\$\$ + ENVIRONMENT \$\$\$

This relationship remains to be tested over time in the school setting. It does however suggest a possible level for investment in the computer facility in relation to hardware and software costs.

SECTION III

DESIGNING SCHOOL COMPUTER FACILITIES

A. STUDENT WORKSTATION DESIGN

Student workstations must be designed to support the efficient carrying out of user activities. A summary of these activities was provided in Table 2. Depending on the nature of the users and the program in which they are involved, some or all of these activities will come into play. Ergonomic studies of some of these activities suggest that a moveable keyboard and screen can be arranged in different ways to accommodate their use as well as the use of related documents. The Canadian Business Equipment Manufacturers Association (CBEMA 1983) in its publication "Ergonomics for Human Effectiveness and Well-being" provides an analysis of workstation equipment arrangements for the following activities: text and data entry, information retrieval, and alternate task activities some of which do not require VDT use. This analysis is summarized in Figure 1: Keyboard and Screen Arrangements.

Applying the dimensions typical of microcomputers used in schools to the arrangements described in Figure 1 suggests minimum top dimensions of 650 mm x 1000 mm (25 in x 40 in) for a student workstation to be used only for text and data entry and retrieval. Dimensions of 760 mm x 1220 mm (30 in x 48 in) would be preferable where extensive writing and reading of non-VDT material are also to be carried out. If the workstation will be used alternately for computer use and then for instruction not requiring computer use, the L-shaped configuration should be considered. Minimum outside dimensions of an L-shaped workstation should be 1220 mm x 1220 mm (48 in x 48 in) with inside dimensions of 610 mm x 610 mm (24 in x 24 in) with preferable dimensions of 1500 mm x 1500 mm (60 in x 60 in) and 750 mm x 750 mm (30 in x 30 in) respectively. (See Figure 2).

The NIOSH recommendations (Table 6) suggest that the height of the keyboard home row be in the range of 740 - 790 mm (29-32 in). For high profile (80 mm) (3 in) keyboards this would require a workstation height of 660 mm (26 in). New, low profile keyboards (25-40 mm) (1-1.5 in) will permit a workstation height of 700 mm (27.5 in) thus providing more knee space as well as a uniform workstation height for both writing and keyboard use. Footrests should be available for students who need them.

Further, it is suggested that a few fully-adjustable commercial workstations be acquired to accommodate physically handicapped students and to train all students in adjusting ergonomic workstations to enhance their comfort and productivity. Sample non-adjustable workstations are shown in Figure 2.

Student workstation design should provide for flexibility for grouping, and should facilitate individual assistance by the teacher. Adequate provisions should also be made for placement of peripheral hardware devices and for necessary cabling (See Electrical Design Criteria).

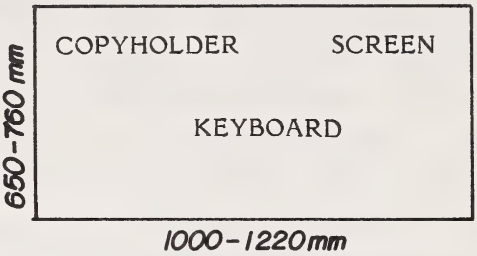
FIGURE 1

WORKSTATION KEYBOARD AND SCREEN ARRANGEMENTS

(CBEMA 1983)

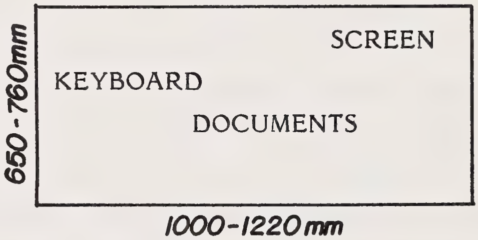
TEXT AND DATA ENTRY

Entering text or other data means intensive use of both hands. In the preferred position, the keyboard is directly in front of the operator and the screen and copyholder are side by side.



INFORMATION RETRIEVAL

Information retrieval often means using one hand on the keyboard while thumbing through documents with the other. Preference is for the keyboard slightly to one side and the screen to the other with note taking documents directly in front and between the keyboard and screen.



ALTERNATE TASKS

An L-shaped work surface is well suited to an operator performing computer tasks and writing tasks alternately. This arrangement allows the operator to swivel the chair between tasks.

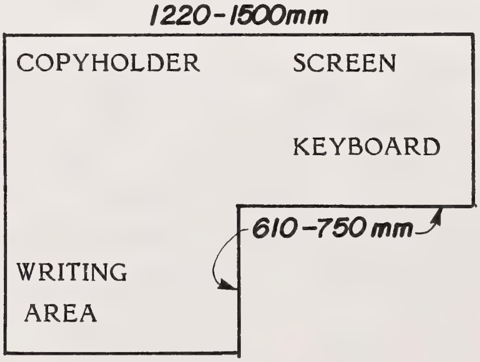
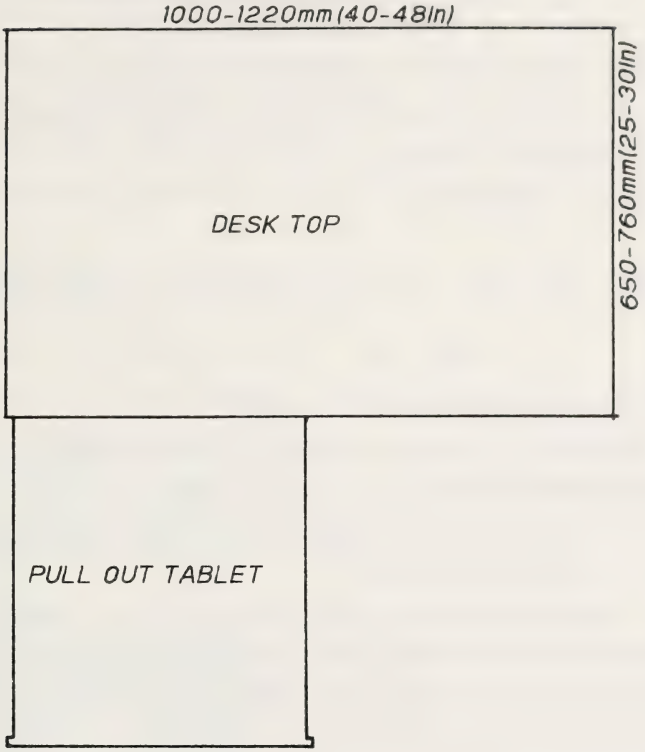
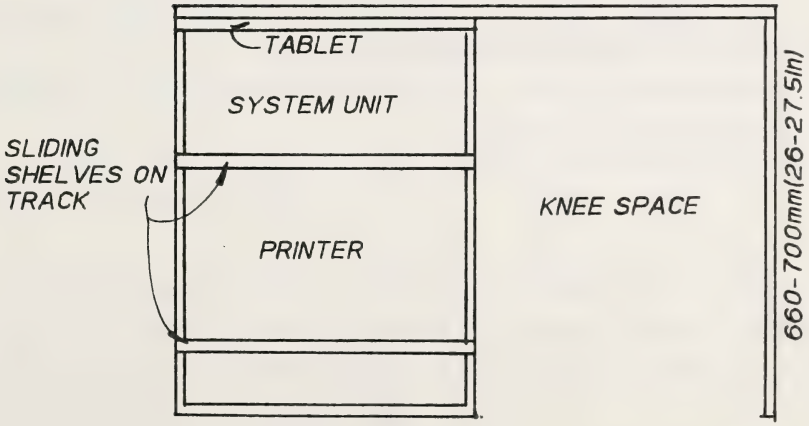


FIGURE 2

STUDENT WORKSTATION DESIGN



PLAN VIEW



FRONT ELEVATION

As important as the workstation design, is the selection of an ergonomically correct chair. Springer suggests the following criteria of good chair design:

1. Provision of anatomical support, "goodness-of-fit";
2. Support of working postures through a range of motion and easy transition from one task to the next;
3. Stability in any position.

He further notes that a workstation chair should have the following characteristics:

1. A rotatable, stable base with castors;
2. A contoured seat whose front edge curves downward to avoid cutting off leg circulation and whose rear curves upward to cradle the hips and pelvis;
3. The seat must not be too large: 400 mm (16 in) front to back and between 495-545 mm (19-21 in) wide;
4. Seat height should be adjustable a minimum range of 380-535 mm (15-21 in);
5. The backrest should have a forward curve to support the lumbar spine and an opening of 100-150 mm (4-6 in) between the backrest and the seat;
6. The entire backrest should adjust in height a minimum of 80 mm (3 in);
7. The backrest should pivot forward and backward from $+15^{\circ}$ to -35°;
8. If arms are provided, they should not be longer than 250 mm (10 in);
9. The chair covering should be a durable knitted fabric which permits air circulation and provides a non-slip surface;
10. User controls should be easy to locate and operate but not interfere with the operator or adjacent equipment.

B. COMPUTER LABORATORY DESIGN

1. Laboratory Configurations

Laboratory configurations should be designed to support effectively the user activities required by the programs being offered. Workstation orientation within the laboratory must accommodate both teacher and student activities (Table 2). Limitations on possible configurations appear to result from the teaching style adopted and from the grouping of students for instruction and practice.

If a laboratory is intended only as a computer resource room and speaking/listening activities are not a major occurrence, orientation of workstations does not present a significant problem. The objectives to be achieved relate to provision of adequate privacy between workstations, noise control, reduction of glare on VDT screens, accommodation of cabling, access to peripherals, and provision of sight lines long enough for visual relief from extended focusing on the screen. The latter considerations make the placement of workstations so that the student directly faces a wall within 760 - 1000 mm (30-40 in) undesirable.

If a laboratory will be used for teaching involving extensive speaking, listening and note taking as well as VDT practice, provision must be made for users to have periodically a common orientation to the instructor. If a laboratory will be used for group discussion and practice, as in a group programming project, an orientation of group members toward the rest of the group must be provided.

Laboratory designs should be flexible to accommodate hardware advances over time.

An analysis of laboratory configuration is provided in Table 7. Sample laboratory layouts are shown in Figures 3-5.

With regard to laboratory size, it is suggested that an area in the range of 4.3 - 4.7m^2 (46 - 50 sq. ft.) per workstation be allocated with an additional 20-30m^2 (215 - 325 sq. ft.) of space provided adjacent to the main laboratory for secure storage, noisy peripherals and for maintenance use.

A functional evaluation checklist for assessing existing laboratories is provided in Table 8. (Branson)

TABLE 7

LABORATORY CONFIGURATION ANALYSIS

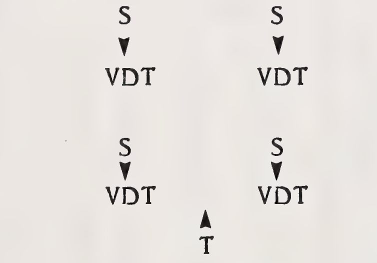
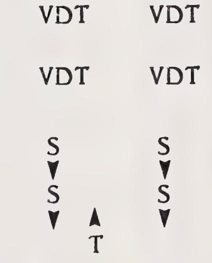
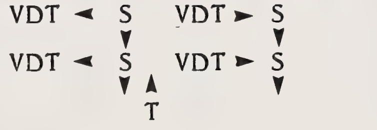
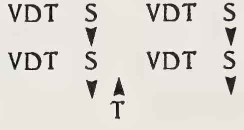
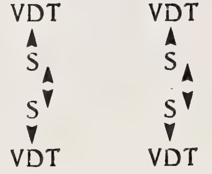
Teaching Style Student Grouping	Integrated Teaching/Practice Activities	Separated Teaching Activities	Separated Practice Activities
Ungrouped	Individual instruction and practice. No special workstation orientation required. Orientation to VDT required.	Individual instruction. No special workstation orientation required. Orientation to VDT not required.	Individual practice. No special workstation orientation required. Orientation to VDT required.
Grouped	Workstations must have common orientation toward the teacher. Orientation to VDT is also required.	Students must have a common orientation toward the teacher. Orientation to VDT not required.	Individual and/or group practice. Orientation toward other group members is required. Orientation to individual VDTs is required.
Composite Configurations (S - Student) (T - Teacher)			(Individual practice only) NO SPECIAL CONFIGURATION
			(Individual and group practice) 

FIGURE 3

COMPUTER LABORATORY WITH SEPARATE PRACTICE AND TEACHING AREAS

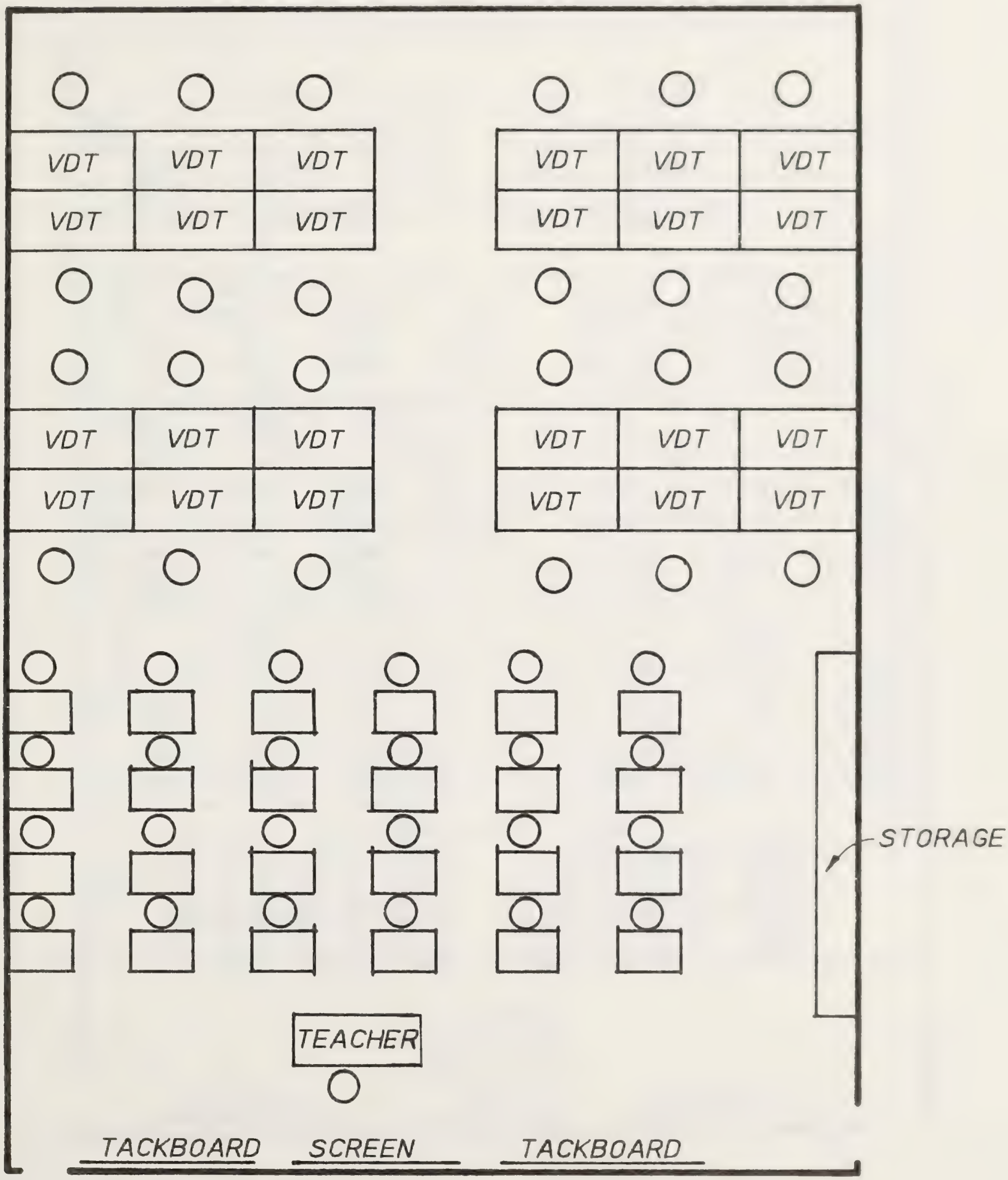


FIGURE 4

COMPUTER LABORATORY DESIGNED FOR GROUP WORK PROJECT

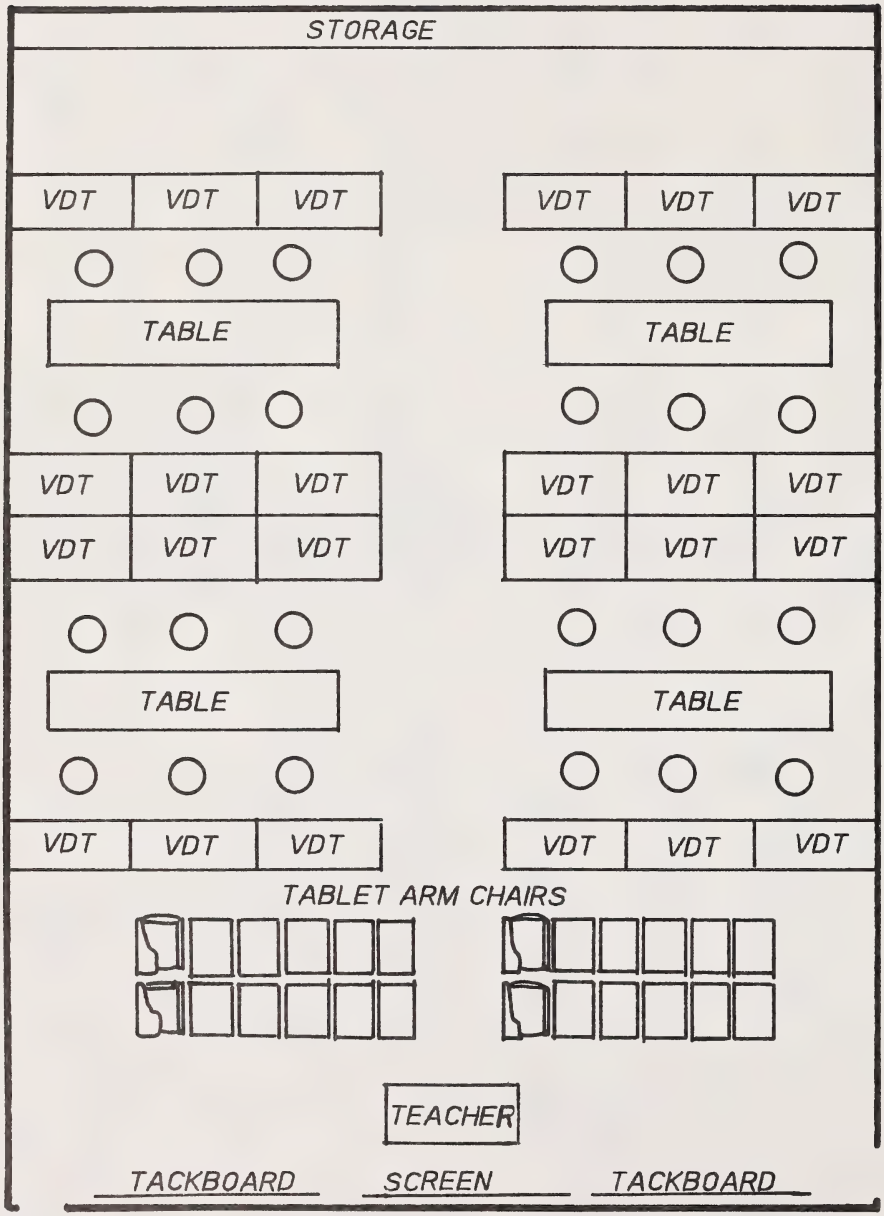


FIGURE 5

COMPUTER LABORATORY WITH INTEGRATED PRACTICE AND TEACHING AREAS

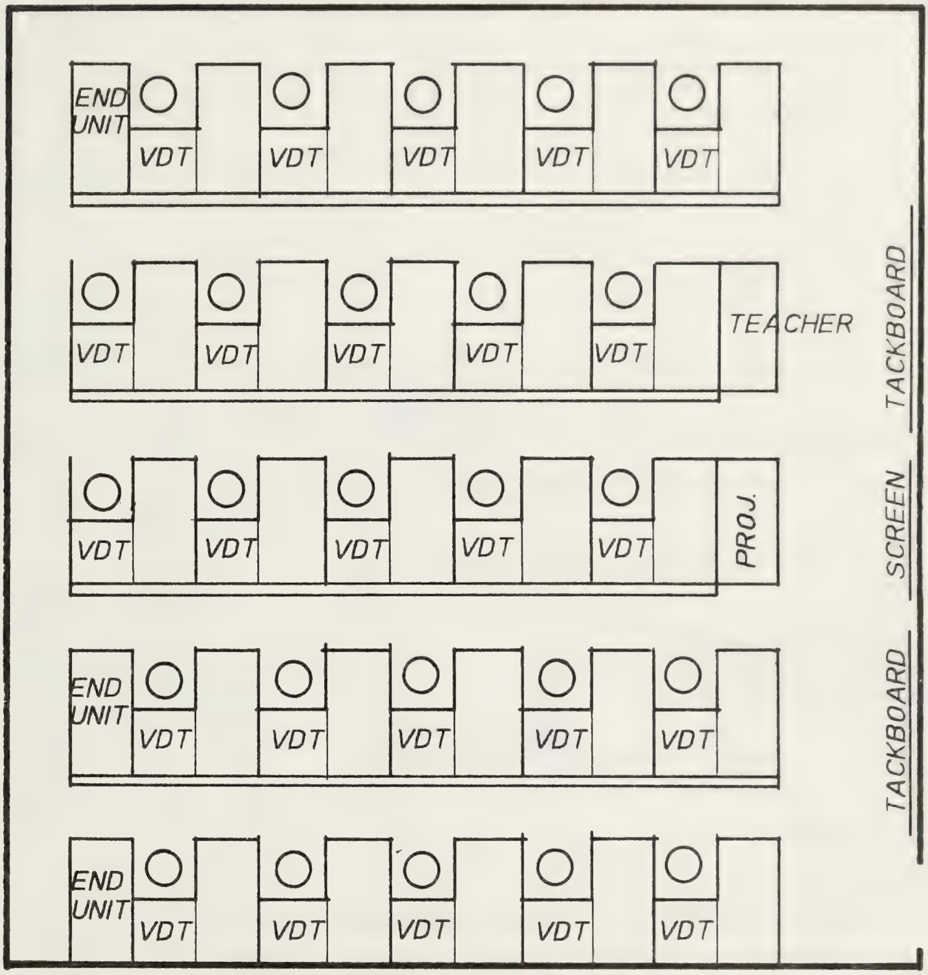


TABLE 8

BUSINESS EDUCATION LAB - FUNCTION EVALUATION CHECK LIST

School: ____________________ Room#: ____________

Room Designation (Primary Lab Utilization): ____________________

Date: ____________________

Current Year's Utilizations:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________

Functional Factors	Assessment (Acceptable/ Inadequate)	Comments/Action
Orientation: a. Location - proximity to other labs - service accessibility - circulation patterns - safety		
Security: a. Interior/Exterior b. Alarm System c. Door Security d. Machine Identification		
Room Basics: a. Room Size b. Room Shape c. Cabinets d. Shelving e. Boards (black, dustless) f. Tackboards g. Other/Alternatives		

TABLE 8
(Continued)

Functional Factors	Assessment (Acceptable/ Inadequate)	Comments/Action
Electrical Supply: a. Adequate Outlets b. Suitable Configuration c. Control Panel d. Circuit Capacity e. Filtering Needs Lighting: a. Adequate Levels b. Control Capability c. Blinds/Drapes d. Glare Control		
Acoustics: a. Noise Levels b. Noise Control Capability		
Heat, Ventilation, Humidity: a. Heat-adequate Control b. Ventilation-adequate Supply c. Humidity-adequate Levels		

Summary Statement:

(Branson 1985)

2. Architectural Design Criteria

a. Access

Security considerations suggest that access to the computer laboratory should be controlled. This is best achieved by locating the laboratory away from exterior building walls. Modifications will have to be made where the computer laboratory will be used outside of normal operating hours; for example, to serve adult education programs. Adequate wheelchair access should be provided.

b. Acoustics

Careful attention must be given to room acoustics because normal classroom noise levels will be supplemented by noise arising from computer printers, disc drives, audible cursor controls, voice synthesizers and by increased airflow from ventilation and air conditioning systems. Overall noise ratio should be about NR 45 - 50 (IBM 1984). Acoustic control should be addressed through ceiling, wall and floor finishes and acoustic insulation of air ducts.

c. Colour

Walls should have a matte finish in a neutral appealing colour. Pastel tones and a greater use of dusty colours and a palette of earth tones is suggested. Cohen in a recent article in "Computer Data" notes the effects of colours as follows: red - warm and stimulating, blue - cool, sedative and depressing, yellow - warm and capricious, green - pleasant and healthy, orange - stimulating, and purple - dignified and reserved. Murals might be considered to provide visual relief from periods of intense visual concentration on computer screens.

d. Dust Control

In order to reduce maintenance problems with computer disc drives, materials and room accessories should be selected which are readily cleaned and which do not contribute dust to the room environment. In particular, chalkboards should be replaced with overhead projection screens or whiteboards, although the latter are not entirely dust free. Windows should be sealed.

e. Natural Light

The use of natural light must be carefully planned to avoid both direct screen reflections and also ceiling glare. An overall light level in the range of 400 - 700 lux (37-65 foot-candles) is recommended (Yeaman). Natural light levels are in the range of 1 000 lux (storm cloud cover) to 100 000 lux (9290 foot candles) (unobscured sun) (IBM, 1984). Natural light, if any, must be attenuated and provided in a direction perpendicular to VDT screen orientation.

f. Security

Security provisions should include fire resistant walls which extend from true floors to true ceilings. Skylights and windows should be barred. Automatic fire doors should be considered to control smoke damage to computers as well as for fire-spread control. Storage for computer tapes and discs should be fire-, water-, and smoke-proof. (AFIPS). Remote or off-site storage of data backups should be provided. Equipment should be attached to furniture.

g. Static Electricity Control

Floor materials should be selected which resist static electricity build-up. Consideration should be given to providing a vapour seal envelope for the laboratory by using vapour barriers and sealant paints for the lab. (Holscher, 1984). Humidity control assists in reducing static build up. Triple glazing should be considered to reduce window fogging resulting from inside humidity conditions in cold weather.

h. Storage

Storage (some lockable) should be provided for computer supplies and student and teacher reference material.

3. Electrical Design Criteria

a. Cabling

Electrical raceways can be incorporated into student workstations. Raceways should be large enough to provide for cables for: regular power, clean power, telephone data lines, local area network communication lines. (Schneider). As an alternative, cable hangers can be provided inside workstations with wires being bundled using nylon ties. Raceways should connect to room systems by raceways located in floors, walls or ceilings. If freestanding poles are used to communicate to ceiling raceways they should be placed against walls or otherwise secured to withstand severe classroom usage which greatly exceeds that normally found in office environments. All raceways should be readily accessible to permit cable changes, extensions and repairs, but should not obstruct vision.

b. Communications

In addition to intercom communication, provision should be made for regular phone service through the school switchboard and for separate dial-up lines to computers with modems. The latter should by-pass school switchboards and have no extensions which could cause data line disconnection. Provision should be made for installation of a local area network.

c. Fire and Smoke Protection

Fire and smoke alarm systems should automatically close computer room doors and cut off all air supply to the computer room. The latter is particularly important because a fire in a remote part of the building can still cause severe damage to computers from circulated smoke. Only halogen-type fire extinguishers should be provided in computer labs. Use of sprinkler systems should be avoided. Computers and peripherals should be provided with plastic covers which can be pulled on when computers are not in use. Such covers have proven useful in reducing damage from fire, smoke, water and ambient dust. Fire resistant construction should be utilized when feasible.

d. Lighting

Artificial lighting for the computer laboratory should be in the range of 400 - 700 lux (37 - 65 foot candles) (Yeaman). Light distribution should be as uniform as possible throughout the room. Indirect lighting (Dietsch) should be considered. If fluorescent lighting is used, full spectrum lamps should be considered as a contribution to reduction of eyestrain. Egg crate and prismatic diffusers on fluorescents are inadequate; parabolic diffusers which greatly reduce ceiling glare should be used.

e. Power Supply

In order to reduce computer maintenance cost as well as to protect against data loss and downtime, computers should be provided with clean power. Cook and Holscher recommend that a recording power line monitor be installed for several weeks to determine the nature of power supply problems at the laboratory location. Subsequently, appropriate equipment should be installed either, on a room or on a computer basis, to control spikes, surges, noise (electromagnetic and radio-frequency). An uninterruptible power supply (UPS) should be considered for key computers where data loss through power interruption would cause significant recovery costs. As a minimum, computer power supply and isolated grounding should be provided directly from a main power panel. Master switching for computers should be provided in each laboratory with key controls to prevent accidental or malicious shutdowns. This provision is needed for the teacher to control learning-teaching activities. Individual workstation switching should also be provided. The installation of equipment with strong magnetic fields in adjacent rooms should be avoided.

f. Security Systems

In addition to fire and smoke protection systems, consideration should be given to provision of intrusion alarms.

4. Mechanical Design Criteria

a. Comfort Conditions

Normal comfort conditions are sufficient for trouble-free micro-computer functioning. It is suggested (Cohen & Cohen) that temperatures be maintained in the 20 - 22°C range and humidity in the 40 - 60% range. In the Alberta winter setting, a range of 20 - 30% is more practical. The maintenance of these ranges may require special treatment. Goldstein notes that a typical computer terminal gives off as much heat as a person. It may well be that the additional heat load in a computer laboratory will require the provision of cooling at certain times of the year. Goswami suggests the provision of cooling by way of a package unit supplemented by an in-room humidifier to maintain adequate humidity for dust and static electricity control. Miller notes that adequate ventilation assists with ion depletion problems associated with VDTs.

b. Acoustics

Because of the anticipated higher noise levels in computer laboratories, consideration should be given to minimizing the noise of airflow to the computer lab.

c. Dust Control

Adequate humidification will contribute to air particle control. However, consideration should be given to other control measures such as recirculation of laboratory air combined with supplemental filtration. (Cohen & Cohen).

d. Fire and Smoke Control

It is important that HVAC systems be controlled through the heat and smoke detector system to cut off air circulation to the computer lab. Halogen fire extinguishers should be provided in the lab. Sprinkler systems should be avoided.

e. Utilities

It is suggested that a sink be provided in a laboratory back-up room as a general aid to maintaining cleanliness and for hand washing after printer ribbon changes.

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